Uncertainty about Future Climates

EES 3310/5310

Global Climate Change

Jonathan Gilligan

Class #20: Wednesday, March 10 2021

Pielke and Nordhaus

Pielke and Nordhaus

Pielke:

Although some scientists believe that there may be “tipping points” … no one knows if or when there might be a threshold effect.

Nordhaus:

Humans are in effect spinning the roulette wheel when we inject CO_2 and other gases into the atmosphere. The balls may land in the favorable black pockets or in the unfavorable red pockets, or possibly in the dangerous zero or double-zero pockets.

Principles of Tipping Points

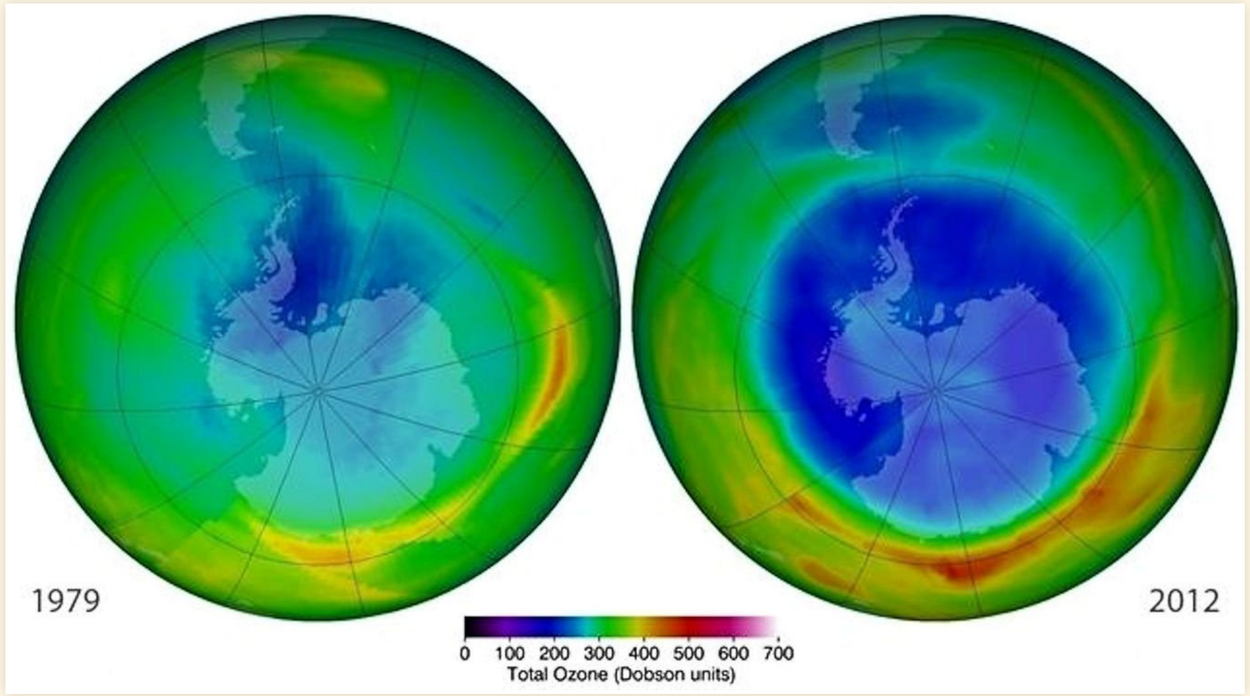
- Ordinary positive feedbacks amplify changes
  (hot → hotter, cold → colder).
  - Small positive feedbacks amplify but the *system remains stable*.
- If positive feedbacks are too strong they become *self-perpetuating*.
  - Secondary forcing from feedback creates *unstoppable change*.
- If feedback *strengthens with warming*:
  - Tipping point: feedback becomes strong enough
    to continue warming independent of external forcing.
- **Not all positive feedbacks have tipping points.**
- **Hard to predict** when a positive feedback might go from *amplifying* to *runaway* (tipping point).

Stratospheric Ozone

- Ozone is a naturally occurring molecule in the stratosphere
  - From 15–35 km altitude
- Blocks harmful ultraviolet (extreme shortwave) radiation
  - Disrupts DNA and proteins in the lens of the eye
  - Causes skin cancer
  - Causes blindness from cataracts
- Scientists have measured ozone from the ground since the 1920s
  - Useful for understanding winds and weather

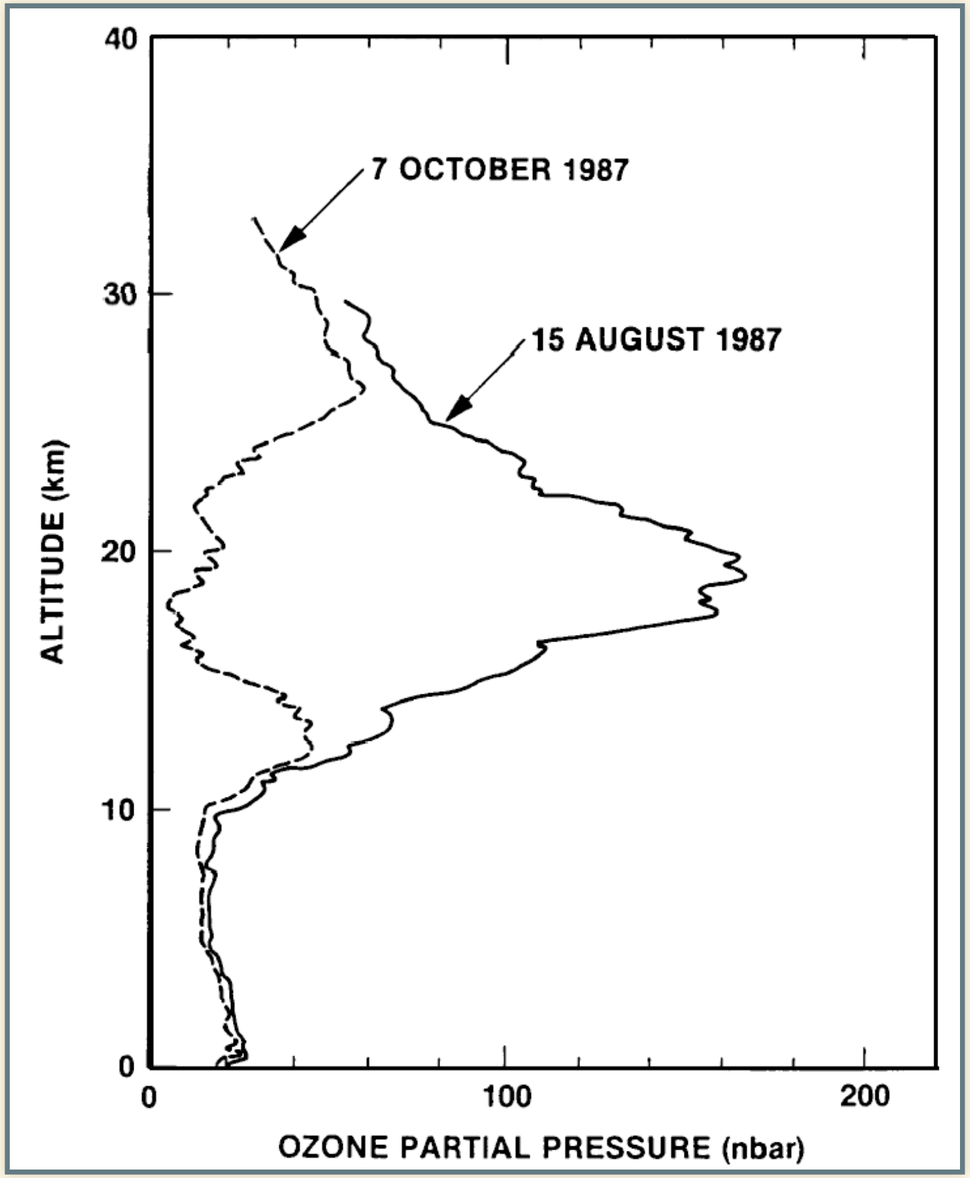
Stratospheric Ozone Depletion

- 1974: Scientific prediction:
  - Chlorofluorocarbon chemicals will destroy ozone
  - Scientists believed ozone destruction would be gradual
- September 1980: Scientists in Antarctica see ozone go to zero in a matter of days
- 1985: Announcement: Discovery of a giant hole in the ozone layer over Antarctica every spring
- Tipping point:
  - Stratospheric chlorine < 2 parts per billion: No ozone hole
  - Stratospheric chlorine > 2 parts per billion: Ozone hole appears

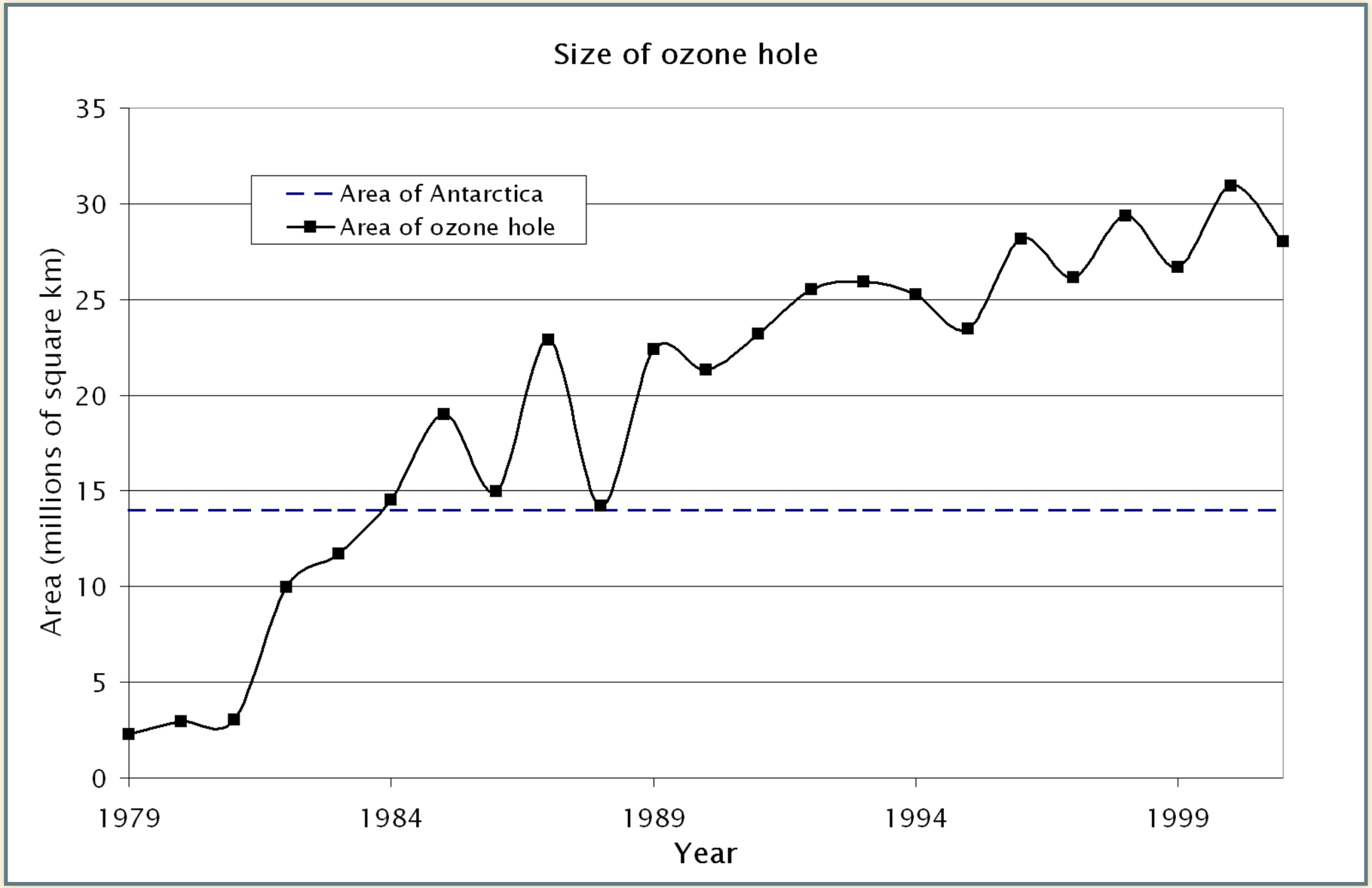


Discovery of the Ozone Hole

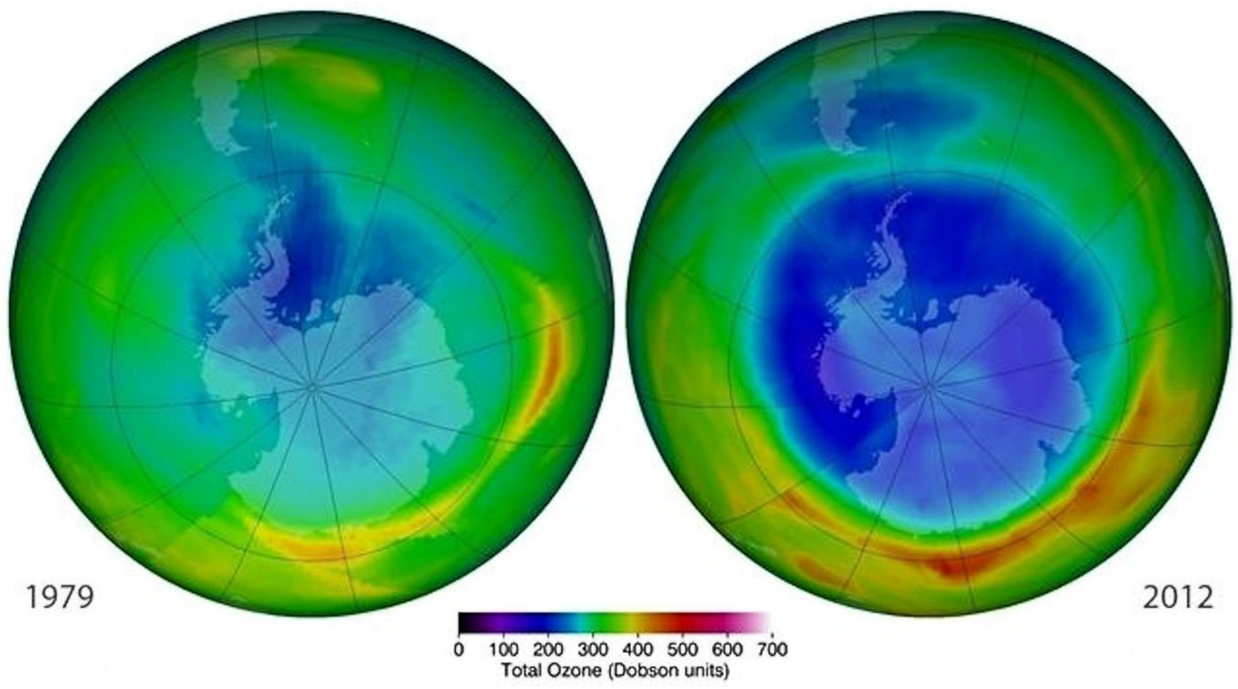
- Halley Bay Antarctica
  - British meteorological station
  - Measured ozone every month from 1958
- Antarctic Winter
  - June–September
  - No sun for months
- September 1980
  - Shortly after the sun rose, ozone disappeared
  - Ozone returned a few months later
  - Station head Joe Farman thought his instrument must be broken
    - Ordered a new instrument from England
    - The next September both instruments saw ozone disappear
  - 1984: Farman reports ozone hole
    - NASA had launched Total Ozone Mapping Spectrometer in 1979
      - Why hadn’t it seen an ozone hole
    - NASA had programmed the computers to ignore crazy low ozone values



Growth of Ozone Hole

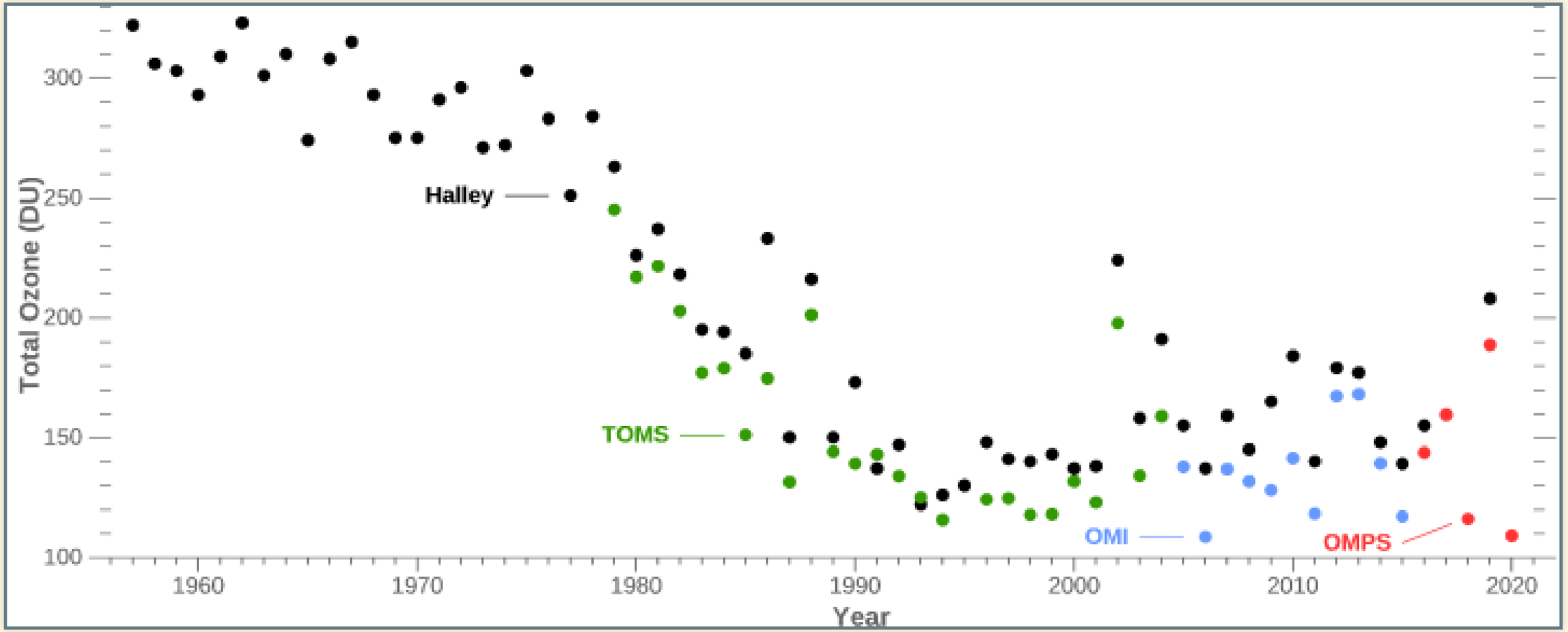


Ozone Policy

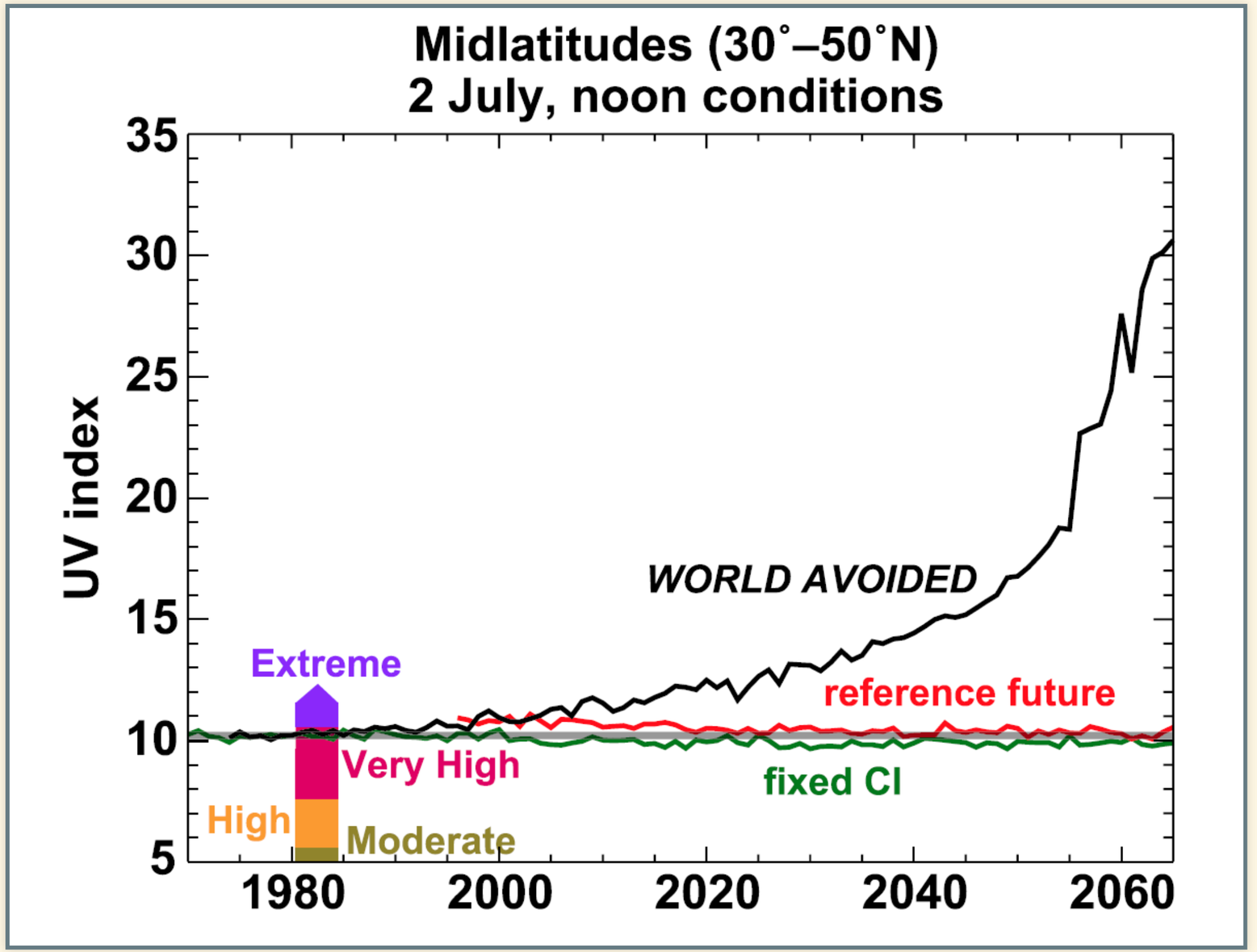


- 1970s: Significant scientific uncertainty
- Decision to take action without waiting for certainty
- Discovery of hole: tipping point
- Flexible policy (renegotiate details every two years)

History of Ozone over Halley Bay



Success: Avoided Futures

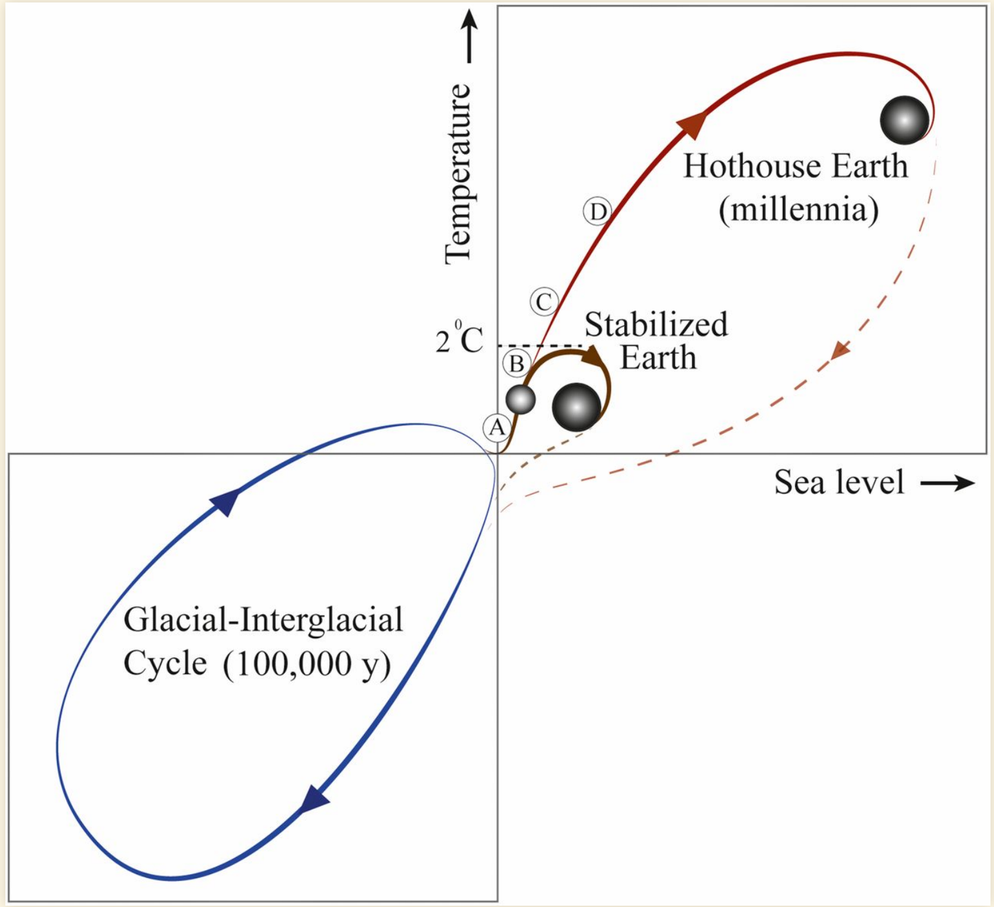


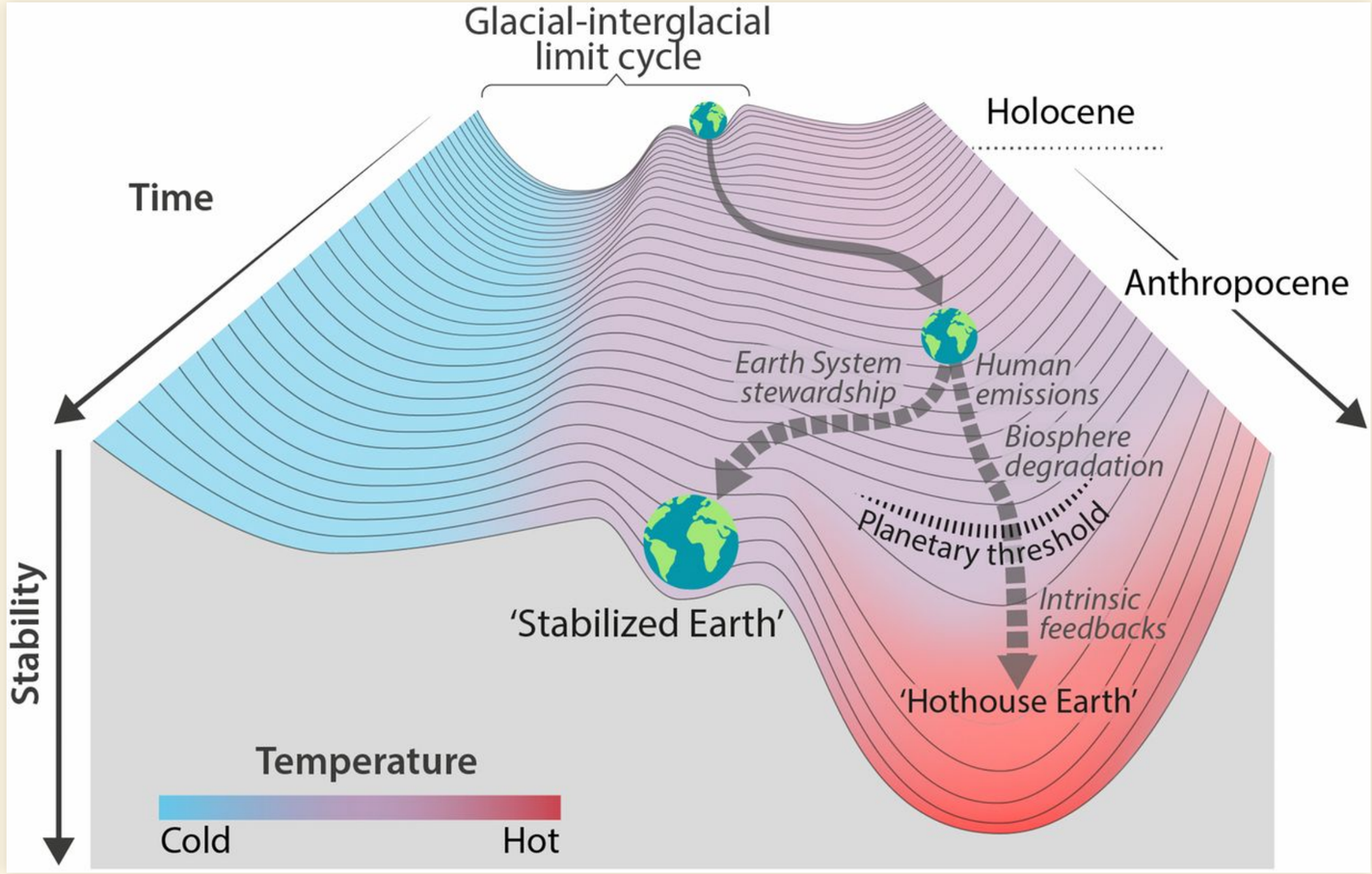
Important Note:

- The ozone hole is completely different from global warming
- Caused by chemical reactions with chlorine atoms
- However:
  - CFC chemicals that destroy ozone are also powerful greenhouse gases
  - Ozone depletion is temperature-sensitive
    - Hole over Antarctica because of very cold stratosphere (much colder than arctic)
    - Global warming cools stratosphere
    - If we had not stopped production of CFC chemicals An ozone hole might have started over arctic too.

Climate Tipping Points?

- *Climate Casino*: No big danger of fast tipping points if warming stays less than 3°C
- Recent research: West Antarctic Ice Sheet may have already crossed irreversible tipping point.
- New research suggests that global tipping points could occur as low as 2°C





W. Steffen *et al.*, PNAS 115, **8252** (2018). doi: 10.1073/pnas.1810141115

Early Warnings of Tipping Points?

Geophysical Research Letters

RESEARCH LETTER
10.1029/2020GL088503

Early-Warning Signals for Critical Temperature Transitions

Chenghao Wang[1,2], Zhi-Hua Wang[1], and Linda Sun[1,3]

[1]School of Sustainable Engineering and the Built Environment, Arizona State University, Tempe, AZ, USA, [2]Department of Earth System Science, Stanford University, Stanford, CA, USA, [3]Horace Greeley High School, Chappaqua, NY, USA

- 2020: Early warning signs of tipping points in temperature can show up as a slowdown of the recovery from extreme heat events.
- The paper claims to see such a slowdown in recent heatwaves around the world.
- This is one paper, and the results will need to be confirmed by other scientists before we can be confident they are right
  - Don’t fall into cherry picking!

Ice-Melting and Ocean Tipping Points

Risk of tipping the overturning circulation due to increasing rates of ice melt

Johannes Lohmann[a,1] and Peter D. Ditlevsen[a]

PNAS 2021 Vol. 118 No. 9 e2017989118 https://doi.org/10.1073/pnas.2017989118

- Melting ice in the arctic may be close to creating a tipping point for the Atlantic conveyor belt current

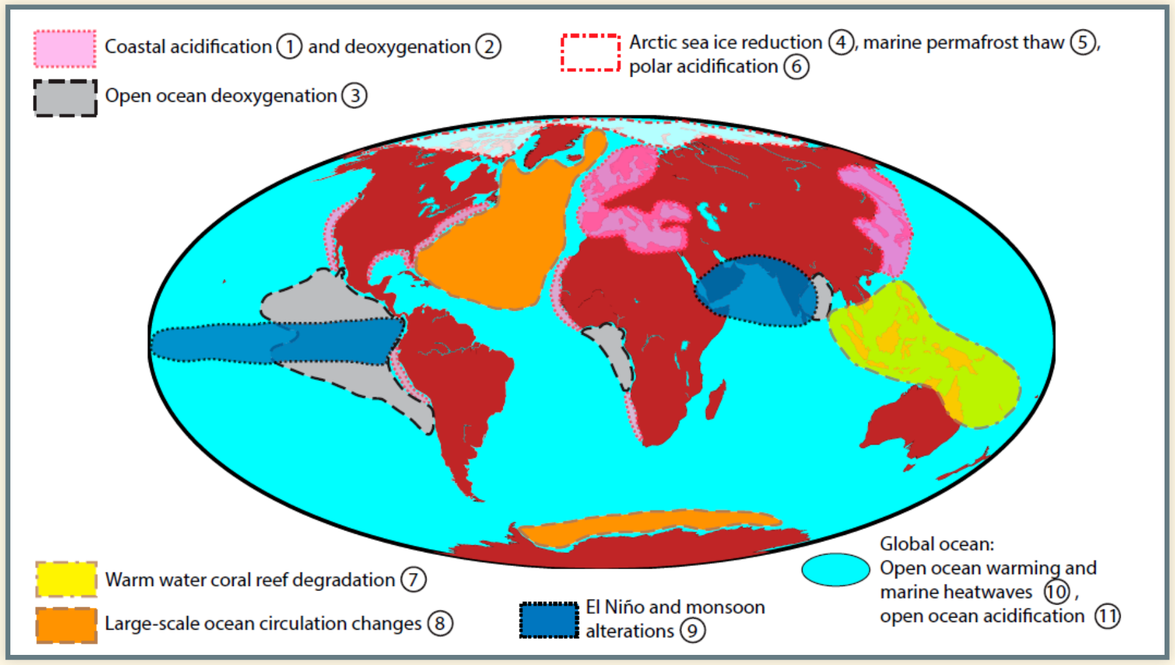
Ocean Tipping Points

- Climate change + acidification + nutrient pollution + ecosystem changes (overfishing, invasive species, etc.)
  - Combination can produce abrupt tipping points:
    - Quiet before we cross them
    - Rapid, irreversible change after we cross them irreversible change

The quiet crossing of ocean tipping points

Christoph Heinze[a,b,1], Thorsten Blenckner[c], Helena Martins[d], Dagmara Rusiecka[a,b], Ralf Döscher[d], Marion Gehlen[e], Nicolas Gruber[f], Elisabeth Holland[g], Øystein Hov[h,i], Fortunat Joos[j,k], John Brian Robin Matthews[l], Rolf Rødven[m], and Simon Wilson[m]

PNAS 2021 Vol. 118 No. 9 e2008478118 https://doi.org/10.1073/pnas.2008478118



Candidates for abrupt tipping points

Goals for Climate Policy

Goals for Climate Policy

- Limit temperature rise?
- Limit greenhouse gas concentrations?
- Focus only on CO_2?
- Focus broadly on all kinds of climate change (natural and human)?
- What do Pielke and Nordhaus say about these questions?
- What do you think?
- Pielke:

> *"A narrow focus on carbon dioxide is double-edged: it gives priority to a very important aspect …, but it can obscure the fact that … climate change involves so much more."*

Scientific Uncertainty

- How does scientific uncertainty affect policy?
- Should we wait for more certainty before acting?
- What do Pielke and Nordhaus say?
- What do you think?

- Nordhaus:

  “A sensible policy would pay an insurance premium to avoid playing the roulette wheel.”

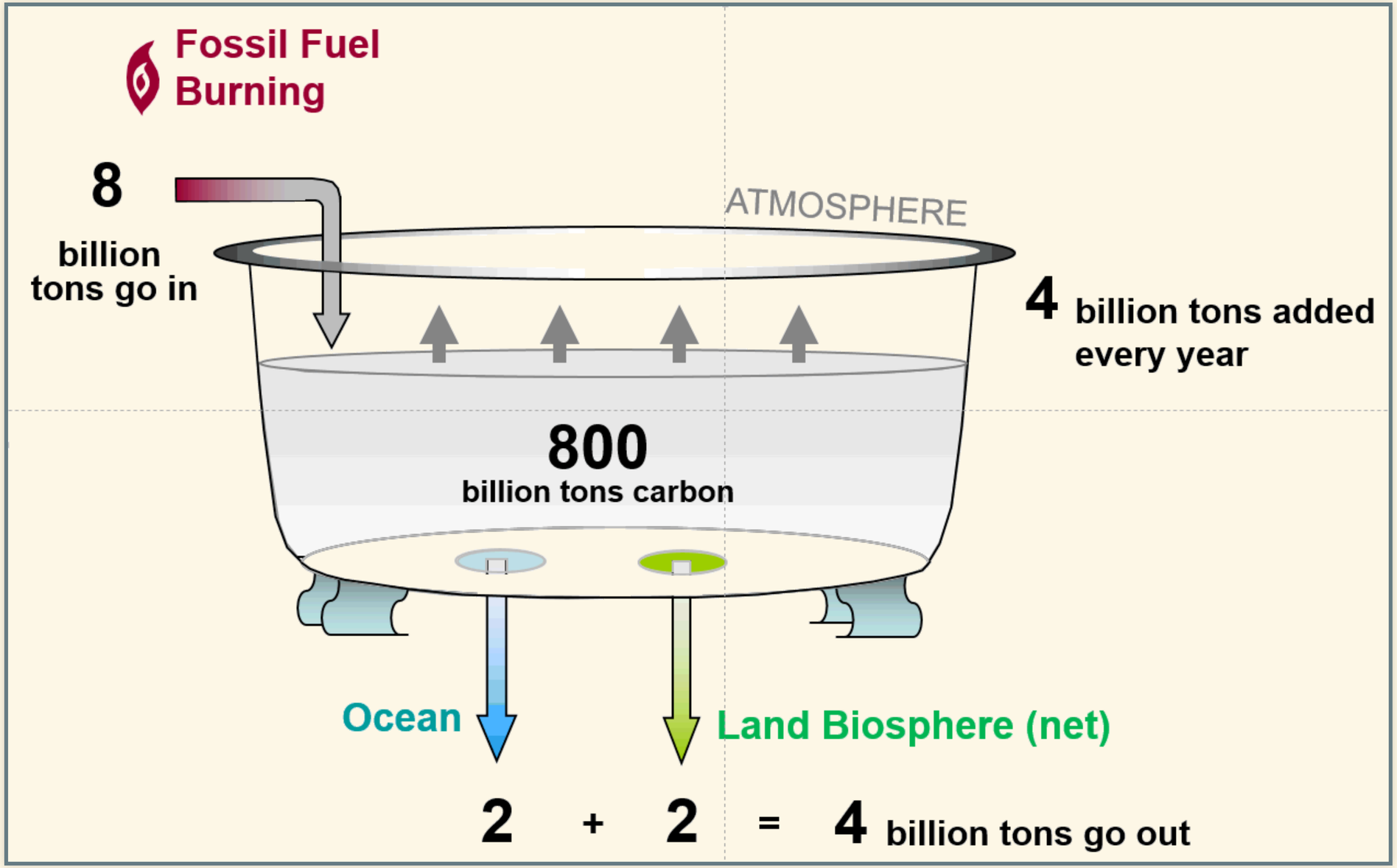
  “The cost of delaying action for 50 years … is [estimated] as $6.5 trillion.”

- Pielke:

  “Policy makers routinely make decisions … with a similar (or even less well-developed) state of understanding.”

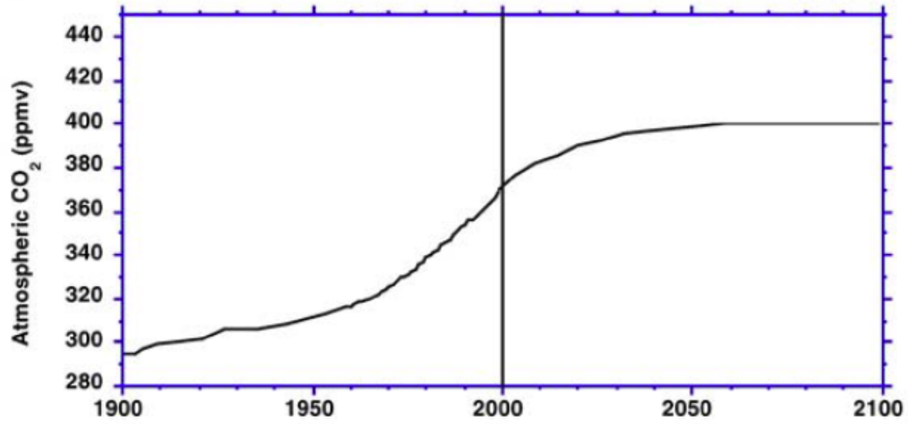
Bathtub model

Bathtub model

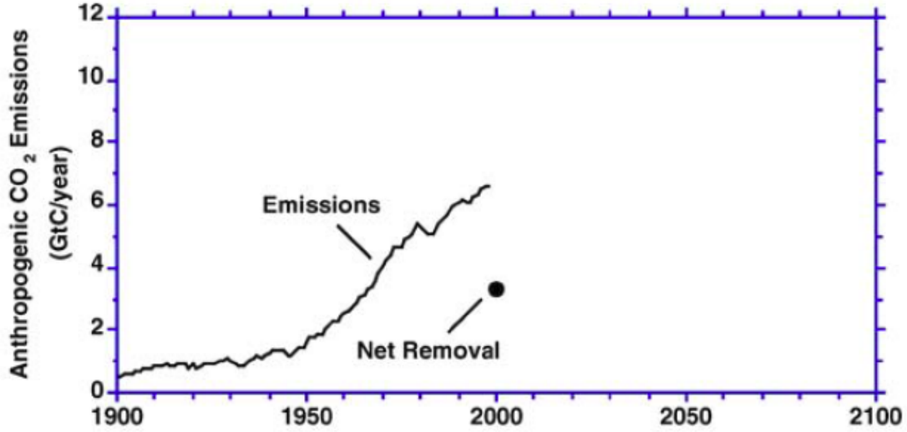


Bathtub model

Now consider a scenario in which the concentration of CO_2 in the atmosphere gradually rises to 400 ppm, about 8% higher than the level today, then stabilizes by the year 2100, as shown here:

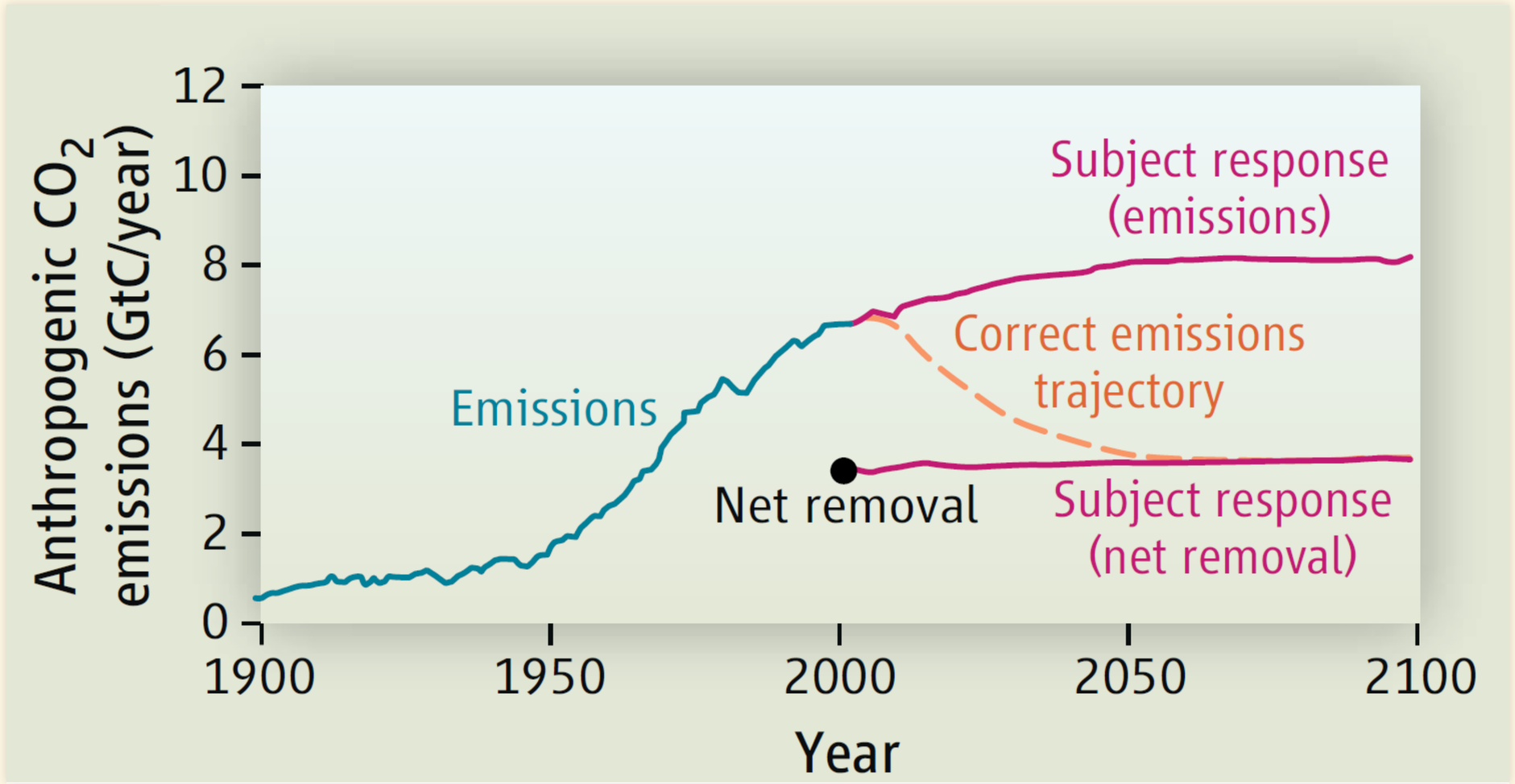


1. The graph below shows anthropogenic CO_2 emissions from 1900-2000, and current net removal of CO_2 from the atmosphere by natural processes. Sketch:
   a. Your estimate of likely future net CO_2 removal, given the scenario above.
   b. Your estimate of likely future anthropogenic CO_2 emissions, given the scenario above.



J.D. Sterman, Science **322**, 532 (2008).

Bathtub model



J.D. Sterman, Science **322**, 532 (2008).

- 212 MIT MBA and graduate students.
- 60% majored in science or engineering